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# New Evidence on Product Quality and Trade

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## **Abstract**

This paper examines why different countries export different qualities of products. Previous studies have attributed quality dispersion to differences in factor endowments while no empirical work has been done examining the effect of technology on quality. Using panel data on U.S. imports from 58 countries, we find that the export of high quality differentiated goods is associated with both higher stock of physical capital endowments and research and development (R&D) activities. We also observe that foreign direct investment (FDI) has a positive effect on quality, which is consistent with the literature on FDI and intra-industry trade. These results cannot be replicated by using the reduced form OLS price regression which is commonly used in the literature. Instead, we use a two-equation system in price and quantity to identify the determinants of quality.

*JEL Classification:* L15, F11, Q16

*Keywords:* Product Quality, Differentiated Products, Heckscher-Ohlin Model, R&D

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## 1. Introduction

An emerging literature in international trade suggests that countries specialize not only on the quantity and the variety of the products they produce and export, but also on some quality level (Hallak, 2005; Hummels and Klenow, 2005; Schott, 2004). More specifically, some countries tend to export higher quality products while others specialize in cheaper, low-quality varieties. This paper attempts to explain why such quality variations exist. We are especially interested in the linkage between quality and technology. Recent empirical studies have attributed quality dispersion to differences in relative factor endowments but no such work has been done examining the effect of technology on quality. It is important to account for this relationship since quality upgrading is an important strategic variable for both industrialized and developing countries. The former have an incentive to upgrade quality so that they can resist low-wage import competition, while the latter may upgrade quality to accelerate their development process.

A novel feature of this paper is that it employs a two-equation system in price and quantity to answer this question. The standard approach in the literature is to regress quality, which is proxied by a price index, against a set of exogenous variables that are likely to influence it. We argue that this OLS price regression has some weaknesses. Such a regression operates under the assumption that export prices are independent of the quantity exported to each market. Theoretically, this may only be true when firms are price-takers, but the price-taking assumption is inconsistent with models of trade in which quality differentiation takes place. Empirically, price (i.e. unit value) and quantity data are also likely to be correlated, due to classification and recording errors at the port of entry.<sup>1</sup> This paper therefore proposes an estimation framework in which price and quantity are jointly determined. Unlike previous studies, we do not proxy quality with price. Instead, since quality is not directly observed in trade data, we postulate a separate

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<sup>1</sup> See U.S. General Accounting Office (1995).

equation for quality and embed it in the price equation.<sup>2</sup> We show that estimating this equation is tantamount to estimating the quality equation, i.e., if the coefficients in the former equation are statistically significant, the coefficients in the latter are statistically significant as well. An advantage of using this approach is that it allows us to identify the key determinants of quality without constructing an explicit quality index.

This paper thus circumvents some of the concerns surrounding the usage of the word ‘quality’ (Hallak and Schott, 2005; Khandelwal, 2005). In the absence of specific information on product quality in trade data, economists tend to proxy quality with a price index. So, if men’s cotton *t*-shirts from Japan are roughly four times as expensive as those originating from Thailand or if Japanese mercury discharge lamps are ten times as expensive as their identically classified variety in Thailand, the conclusion is that Japan produces better quality *t*-shirts and lamps than Thailand and vice-versa.<sup>3</sup> However, in reality, price dispersions exist not only due to quality differences, but also due to differences in production costs (i.e. trade data contains information on both vertically and horizontally differentiated products). Hallak and Schott (2005) find that for countries like China, Taiwan, and Ireland, price indices tend to underestimate the actual quality of their exports by a significant margin.

In this paper, we use panel data on U.S. imports (equivalently, foreign exports to the U.S.) from 58 countries during 1993-1996. We construct aggregate price and quantity indices for each country, based on cross-country differences in unit values and quantities at a very disaggregate level (SITC 10 digit). We follow the classification of “differentiated” and “homogeneous” sectors by Rauch (1999). We also include homogeneous goods to provide a basis for comparison. For differentiated goods, we restrict the analysis to manufacturing sectors (SITC1=5-8) since they

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<sup>2</sup> This is consistent with Hallak (2005) who posits a positive relationship between price and quality.

<sup>3</sup> Author’s own calculation based on 1995 U.S. import flows from Feenstra (2000).

have the most categories. For homogeneous goods, we focus on the non-manufacturing sectors such as food and agricultural products (SITC 1 = 1-4).

Our findings are as follows. First, we observe that the export of high quality differentiated goods is associated with higher stock of capital (per worker) and research and development (R&D) activities. This is an interesting result, considering that we cannot replicate it using the standard OLS regression. Second, we find that foreign direct investment (FDI) has a positive effect on quality. This is consistent with the literature on FDI and intra-industry trade which suggests that higher levels of FDI are associated with greater trade in vertically differentiated products.<sup>4</sup> Finally, we find that unlike differentiated goods, export prices of homogeneous goods *decrease* with greater FDI inflows and land endowments. This is because countries specializing in agricultural and other homogeneous products (which do not feature a prominent quality margin) may be land-abundant and may also attract less FDI.

This paper thus contributes to two important literatures. The first literature concerns the debate on factor endowment versus technology based explanations of trade patterns. Falvey (1981) and Falvey and Kierzkowski (1987) suggest that capital rich countries are more likely to export higher quality products (since production of high quality goods requires higher capital intensity in production), while Flam and Helpman (1987) argue that quality differences are driven by technological differences rather than endowment differences. Although Schott (2004) and Hummels and Klenow (2005) find strong support for the factor endowment argument – they observe that higher export prices are associated with larger endowments of capital – no work has been done examining the linkage between quality and technology. This paper therefore attempts to document the latter relationship, although we do not directly test all the implications of the Flam and Helpman (1987) model.

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<sup>4</sup> See Reganati and Pittiglio (2005) for a survey of this literature.

The second literature focuses on the relationship between FDI and vertical trade. Studies by Reganati and Pittiglio (2005) and Caetano and Gallego (2006) suggest that FDI and vertical intra-industry trade are positively related for several countries in Europe. Our paper extends this analysis by forging a link between foreign investment and the quality of the host country's exports.

This paper is organized as follows. Section 2 provides an overview of the relevant literature on trade and product quality, including a discussion on the various ways in which quality is defined in the literature. Section 3 presents our theoretical framework, while Section 4 discusses the empirical specification. Sections 5 and 6 discuss the data and the estimation results respectively. Finally, Section 7 makes some concluding remarks and suggests possible extensions to our research.

## **2. The Literature on 'Quality' and Trade**

The earliest theoretical work on 'quality' and trade dates back to Linder (1961). He argues that countries with similar income have similar consumption and production patterns. For example, consumers in rich countries are likely to spend a larger proportion of their income on high quality goods and thus, import high quality goods from other rich countries. In a recent study, Fan (2005) formalizes the Linder hypothesis and suggests that consumer demand for quality depends on their human capital (and income). As a result, countries with larger human capital stock (and income) will demand higher quality goods. In addition, proximity to such demand will provide producers in these countries with a comparative advantage in the production of high quality goods. Hallak (2005) examines the Linder hypothesis using bilateral trade data for 60 countries and finds strong evidence of a positive association between per capita income and demand for quality.

On the supply side, much theoretical work has been done, most notably by Falvey (1981) and Flam and Helpman (1987). Falvey (1981) and Falvey and Kierzkowski (1987) offer a Heckscher-Ohlin based explanation for 'quality' production: countries will specialize in the production of the good which uses its abundant factors intensively. Since high quality goods require higher capital intensity, capital rich countries are more likely to export them. On the other hand, labor abundant countries are more likely to specialize in the export of lower quality products. Unlike Falvey (1981) and Falvey and Kierzkowski (1987), Flam and Helpman (1987) argue that quality depends not on the amount of capital used in production, but on technology. They show that technological progress in the Southern industrial sector forces the North to upgrade quality and the South to take up the production of low quality goods abandoned by the North.

Recent empirical research has focused largely on the endowment-based explanation of quality. Schott (2004) finds that unit values within products vary systematically with exporter relative factor endowments and exporter production techniques, consistent with factor proportions specialization within products. Hummels and Klenow (2005) observe that rich countries export higher quantities at modestly higher prices, which is consistent with these exporters producing higher quality goods. Mora (2002) also finds significant evidence that countries with higher relative levels of income in the European Union (EU) between 1985 and 1996 export predominantly higher quality products, while member states with lower relative level of income tend to specialize in lower qualities.

The literature also considers the relationship between FDI and trade in vertically differentiated products. Chiarlone (2000), Caetano and Gallego (2006), and Reganati and Pittiglio (2005) find that FDI inflows help consumers to satisfy their differentiated demands and allow scale economies to appear in production which in return increases vertical trade. Damijan et al. (2001) also find evidence of a relationship between export volume and foreign capital for firms

located in Central and Eastern European Countries (CEEC). These findings imply that FDI may be an important determinant of quality, since quality differentiation is an important feature of ‘vertical’ trade. The literature on FDI and technology transfer also lends some support to this hypothesis. As Blomstrom and Kokko (1997) suggest, FDI provides an important conduit for both direct technology transfers and indirect intra-industry knowledge spillovers.

### ***2.1. Definition and Measurement of Product ‘Quality’***

Different studies have used different proxies for product quality. Since product quality is not directly observed in trade data, most of these proxies are based on the assumption that price variations contain sufficient information about quality variations. Some of these proxies use cross-country variation in export prices (unit values), while others rely on *both* export and import unit prices. Some of these indices are calculated at the product level, while other indices are constructed at the sectoral level. Hallak (2005) even goes one step further and creates a separate quality index for each country. The following discussion will elaborate on the definition and construction of some of these quality indices.

The Abd-el-Rahman (1991) unit value ratio expresses the export unit value of a given product relative to the import unit value of the same product. Import unit values are used since domestic flows are largely unobservable.<sup>5</sup> The closer is this ratio to 1, the more similar are the home country’s exports and imports in terms of quality. Such exchanges are considered “horizontal.” Products in such sectors may have different proportion of some characteristics, but none has a bigger amount of every characteristic. These products are not expected to show huge price differences. If this ratio is sufficiently far away from 1 (such that it exceeds the limits of the

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<sup>5</sup> See Fontagne, L., M. Freudenberg, N. Peridy (1998) for properties of this ratio.



interval  $[1 - \varepsilon, 1 + \varepsilon]$ , where  $\varepsilon$  is an arbitrary cutoff point), these exchanges are “vertical.”<sup>6</sup> These products have a different amount of every characteristic compared to other products. The quality of these products may be ‘better’ or ‘worse’ than those of other products, depending on whether they have a bigger or a lower amount of these characteristics. These products represent a different positioning on the quality spectrum and are less sensitive to price competition. The Abd-el-Rahman index has been extensively used in the literature, most notably by Chiarlone (2000), Martin and Orts (2001), Mora (2002), Reganati and Pittiglio (2005), etc.

Schott (2004) also uses product level unit values to measure quality. In essence, he estimates quality by calculating unit values of all US imports (equivalently, exports of all other countries) at the product level. The unit values provide substantial variation at a very disaggregate level, and may not be perfect indicators of quality due to underlying product heterogeneity and classification error involving inaccurate recording of units and misclassification of goods.

Hallak (2005) uses a more aggregate price index to estimate quality. More specifically, he uses the Fisher price index, which is the geometric mean of the Laspeyres index and the Paasche price index. The Laspeyres index itself weights the price in each period by the quantities in the base period, while the Paasche price index uses the current period quantities to weight the prices. Hummels and Klenow (2005) also use a variant of the Fisher Price Index to infer the quality margin. They decompose each country’s exports to a given market category into its price and quantity components and compare them across exporters.

A number of studies do not construct any specific quality (or price) indices, but use other ways to estimate quality differences across countries. For example, Hummels and Skiba (2004) estimate quality differences by calculating price variation across all country pairs for products in a given category. This removes certain commodity-specific variation in prices (e.g. a low quality

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<sup>6</sup> The ratio may also take extreme values if export and import prices are influenced by different factors. This can be problematic for cross-country studies.

car might be much more expensive than a high quality stereo system). They also hold the supply side of the model constant so that price variations across importers arise purely due to changes in the quality mix.

Several studies also explore the horizontal dimensions of product differentiation. Instead of equating quality with a price index (under the assumption that all price dispersions occur due to vertical quality differentiation), they allow cross-country variation in prices to be caused by factors other than quality, such as comparative advantage. For example, Hallak and Schott (2005) develop a decomposition methodology that separates observed export prices into quality versus quality-adjusted prices. However, despite allowing for horizontal differentiation, they find that for many countries, there is not much difference between a country's quality index and its price index (notable exceptions include China and Ireland). Khandelwal (2005) also allows for horizontal differentiation by applying the discrete choice methodology in Berry, Levinsohn, and Pakes (1995). He infers countries' unobserved product quality by allowing market shares to influence quality estimates, so that products with larger market shares have higher quality (conditional on price) and vice-versa. This methodology, while useful at a disaggregate level, is computationally intensive and difficult to implement at the country level.

In conclusion, since product quality is not directly observable from trade data, there is a lack of consensus on an appropriate measure of quality. Researchers have traditionally used various price indices to proxy for quality, but this approach ignores the horizontal aspects of product differentiation. On the other hand, efforts to incorporate horizontal differentiation have been relatively scarce and are somewhat difficult to implement at a more aggregate level.

### 3. A Model of Quality Differentiation

In this section, we consider a simple model of quality differentiation which will guide the empirical analysis. This model is inspired by the Armington (1969) assumption that products are differentiated by national origin. Thus, Japanese midsize cars are differentiated from German midsize cars and so on. This assumption is consistent with international production specialization and is often used in the gravity equation (Anderson, 1979).

Assume each country  $i$  produces a unique variety,  $i = 1, \dots, I$  and exports this particular variety to destination country  $j$ . Consumers in  $j$  have preferences which are defined by a CES utility function. These preferences are convex in product variety (i.e. a consumer derives additional utility from consuming different varieties) and symmetric in all goods. The representative consumer in  $j$  maximizes utility given by:

$$U_j = \sum_{i=1}^I \theta_i c_{ij}^{1-1/\sigma}, \quad \sigma > 1 \quad (1)$$

subject to

$$\sum_{i=1}^I p_i c_{ij} \leq I_j \quad (2)$$

In (1),  $\theta_i$  and  $c_{ij}$  are the quality and the quantity of the products produced by  $i$  and consumed by  $j$ . Quality is a utility shifter (i.e., consumers demand products with higher quality) and allows the model to exhibit vertical aspects of product differentiation. For simplicity, we adopt a Dixit-Stiglitz formulation with a single elasticity of substitution  $\sigma > 1$  between goods from different countries, although in the empirical implementation, we will allow  $\sigma$  to vary by

the country of origin. In (2),  $p_{ij}$  and  $I_j$  represent the price of each variety  $i$  and the income in country  $j$ .

Taking first order conditions from (1) and (2) for each country  $i$  and  $j$ , we obtain a relationship between prices, quality, and quantity. More specifically, we find that relative prices between  $i$  and  $j$  are decreasing in the demand for quantity and increasing in the demand for quality. This relationship reflects both individual consumer demand and world demand since preferences are symmetric and prices are identical.

$$\left(\frac{\theta_i}{\theta_j}\right)\left(\frac{c_i}{c_j}\right)^{-\frac{1}{\sigma}} = \left(\frac{p_i}{p_j}\right) \quad (3)$$

We now turn our attention to the producer. There is only one producer in each country, who is a monopolistic competitor in the world market. Production is guided by the following production function:

$$x_i = K_i^{\gamma_1} H_i^{\gamma_2} L_i^{1-\gamma_1-\gamma_2} \quad (4)$$

We use  $K_i$  to denote physical capital,  $H_i$  to denote human capital, and  $L_i$  to denote labor and other resources used in the production of good  $x_i$  in equation (4). The parameter  $\gamma_i$  ( $i = 1, 2, 3$ ) in the production function captures returns to scale. For algebraic simplicity, we assume constant returns to scale production function. This assumption is not too restrictive as our results are also valid for increasing and decreasing returns to scale production functions.

The firm uses these resources (physical and human capital and labor) in such a way as to maximize its profit. The profit function can be written as:

$$\pi(x_i) = p_i x_i - r_i K_i - \tilde{w}_i H_i - w_i L_i \quad (5)$$

In equation (5),  $r_i$  denotes the rental rate on capital  $K_i$ ,  $\tilde{w}_i$  denotes the rental rate on human capital  $H_i$  and  $w_i$  denotes the wage rate earned by labor  $L_i$ . After substituting (4) into (5), we maximize profit to determine the relationship between price and various factor endowments.

$$p_i = \frac{r_i}{\gamma_1 K_i^{\gamma_1-1} H_i^{\gamma_2} L_i^{1-\gamma_1-\gamma_2}} \quad (6a)$$

$$p_i = \frac{\tilde{w}_i}{\gamma_2 K_i^{\gamma_1} H_i^{\gamma_2-1} L_i^{1-\gamma_1-\gamma_2}} \quad (6b)$$

$$p_i = \frac{w_i}{(1-\gamma_1-\gamma_2) K_i^{\gamma_1} H_i^{\gamma_2} L_i^{-\gamma_1-\gamma_2}} \quad (6c)$$

Thus, we have obtained pricing rules for both the consumer (equation 3) and the producer (equations 6a-6c). Without loss of generality, we set equations (3) and (6c) equal to each other. This gives us an expression for the relative consumption between  $i$  and  $j$ .

$$\frac{c_i}{c_j} = \left[ \frac{w_i / w_j}{\left( \theta_i K_i^{\gamma_1} H_i^{\gamma_2} L_i^{-\gamma_1-\gamma_2} \right) / \left( \theta_j K_j^{\gamma_1} H_j^{\gamma_2} L_j^{-\gamma_1-\gamma_2} \right)} \right]^{-\sigma} \quad (7)$$

Equation (7) embodies the world demand ( $c_i$ ), which is equal to the world supply ( $x_i$ ) in equilibrium. The world supply itself must be equal to the domestic production of a particular variety, since each country specializes in one product only. We can thus obtain the market-clearing wage rate, by combining equation (7) with the production function (4):

$$\frac{w_i}{w_j} = \frac{\theta_i}{\theta_j} \frac{L_j}{L_i} \left( \frac{K_i^{\gamma_1} H_i^{\gamma_2} L_i^{-\gamma_1-\gamma_2}}{K_j^{\gamma_1} H_j^{\gamma_2} L_j^{-\gamma_1-\gamma_2}} \right)^{1-\frac{1}{\sigma}} \quad (8)$$

Substituting this market clearing wage rate into the labor market condition (6c) yields the following price relationship:

$$\frac{p_i}{p_j} = \left( \frac{K_i / L_i}{K_j / L_j} \right)^{-\frac{\gamma_1}{\sigma}} \left( \frac{H_i / L_i}{H_j / L_j} \right)^{-\frac{\gamma_2}{\sigma}} \left( \frac{L_i}{L_j} \right)^{-\frac{1}{\sigma}} \frac{\theta_i}{\theta_j} \quad (9)$$

Equation (9) suggests that the relative price between  $i$  and  $j$  will depend on both differences in factor abundance and differences in the quality of the products. We can also obtain a similar expression for relative quantity by substituting the wage equation (8) into equation (7):

$$\frac{x_i}{x_j} = \left( \frac{K_i / L_i}{K_j / L_j} \right)^{\gamma_1} \left( \frac{H_i / L_i}{H_j / L_j} \right)^{\gamma_2} \frac{L_i}{L_j} \quad (10)$$

At this point, we cannot estimate equation (9) since product quality is not directly observed in trade data. We will therefore adopt the following strategy. First, we will postulate a relationship between quality, technology, and relative endowments. Then, we will substitute this expression into the price equation and obtain an equation in terms of *observed* variables only. Finally, we will show that estimating this equation is equivalent to estimating the quality equation. More precisely, if the coefficients in the former equation are statistically significant, the coefficients in the latter equation will be statistically significant as well. This will allow us to identify the determinants of quality without constructing an explicit quality ‘index.’

We now follow the steps outlined above. We begin by hypothesizing a relationship between product quality and some other variables which are likely to influence it. Schott (2004) suggests that physical and human capital per worker are critical to the production of high quality products, so we account for relative factor endowments in our hypothesis. We also include FDI, since Chiarlone (2000), Caetano and Gallego (2006), and Reganati and Pittiglio (2005) find strong

evidence of a positive relationship between FDI and vertical trade. Finally, since Flam and Helpman (1987) point toward technology as a crucial determinant of quality, we include each country's spending on research and development (R&D) as proxy for its technology ( $\phi_i$ ).

$$\theta_i = \left( \frac{K_i}{L_i} \right)^{\lambda_1} \left( \frac{H_i}{L_i} \right)^{\lambda_2} (FDI_i)^{\lambda_3} (\phi_i)^{\lambda_4} \quad (11)$$

The null and alternative hypotheses associated with this relationship are as follows. If factor endowments and technology do not affect the supply of quality, we can expect  $\lambda_i = 0$  for all  $i$ . However, if they affect quality as the literature suggests, we can expect  $\lambda_i > 0$  for all  $i$ .

Substituting equation (11) in (9), we obtain an expression for relative price only in terms of *observed* variables such as relative endowments, technology, and labor force.

$$\frac{p_i}{p_j} = \left( \frac{K_i / L_i}{K_j / L_j} \right)^{\lambda_1 - \frac{\gamma_1}{\sigma}} \left( \frac{H_i / L_i}{H_j / L_j} \right)^{\lambda_2 - \frac{\gamma_2}{\sigma}} \left( \frac{FDI_i}{FDI_j} \right)^{\lambda_3} \left( \frac{\phi_i}{\phi_j} \right)^{\lambda_4} \frac{L_i}{L_j}^{-\frac{1}{\sigma}} \quad (12)$$

We can estimate equation (12) and test the following set of null hypotheses:

$$\lambda_1 - \frac{\gamma_1}{\sigma} = 0 \quad (13)$$

$$\lambda_2 - \frac{\gamma_2}{\sigma} = 0 \quad (14)$$

$$\lambda_3 = 0 \quad (15)$$

$$\lambda_4 = 0 \quad (16)$$

Since  $\gamma_1$ ,  $\gamma_2$ , and  $\sigma$  are non-zero by assumption, testing the set of null hypotheses given by equations (13)-(14) is tantamount to testing  $\lambda_1 = 0$  and  $\lambda_2 = 0$ . Viewed in this manner, estimation of the pricing equation in (12) is thus equivalent to the estimation of the quality equation in (11). As we will see in the next section, the parameters  $\lambda_1 - \lambda_4$  can be identified when the quantity equation (10) and the price equation (12) are jointly estimated.

#### 4. Empirical Strategy

The empirical implementation proceeds as follows. First, we take the logarithm of price and quantity equations (12) and (10) respectively. Since there is only one importer in our data (the U.S.), we do not include the price, quantity, and determinants of its exports in these equations. Instead, we incorporate time dummy variables which subsume the importer-specific effects. We also include land per worker (denoted by  $T/L$ ) as an additional control variable since Hummels and Levinsohn (1995) find a negative relationship between land endowments and the volume of intra-industry trade. The latter can be decomposed into price and quantity margins, so we include land endowments in both the price and quantity equations. Finally, we include a term representing transport barriers in the quantity equation only. As Anderson, Schaefer, and Smith (2006) suggest, quantity flows appear to decline with such barriers but price dispersion does not appear to respond to them. The resulting price and quantity equations are as follows:

$$\ln p_{it} = \delta_c + \psi_t + \alpha_1 \ln \frac{K_{it}}{L_{it}} + \alpha_2 \ln \frac{H_{it}}{L_{it}} + \alpha_3 \ln FDI_{it} + \alpha_4 \ln \phi_{it} + \alpha_5 L_{it} + \alpha_6 \ln \frac{T_{it}}{L_{it}} + v_{it} \quad (17)$$

$$\alpha_1 = \lambda_1 - \frac{\gamma_1}{\sigma}, \alpha_2 = \lambda_2 - \frac{\gamma_2}{\sigma}, \alpha_3 = \lambda_3, \alpha_4 = \lambda_4, \alpha_5 = -\frac{1}{\sigma}$$



$$\ln x_{it} = \delta_c + \psi_t + \mu_1 \ln \frac{K_{it}}{L_{it}} + \mu_2 \ln \frac{H_{it}}{L_{it}} + \mu_3 \ln \frac{T_{it}}{L_{it}} + \mu_4 L_{it} + \mu_5 \tau_{it} + \xi_{it} \quad (18)$$

$$\mu_1 = \gamma_1, \mu_2 = \gamma_2$$

In (17) and (18),  $\delta_c$  and  $\psi_t$  are dummy variables specific to income cohort  $c$  and time period  $t$ . The income cohorts themselves are based on the World Bank's Income Group Classification (2006). The terms  $\nu_{it}$  and  $\xi_{it}$  represent the disturbances in each equation.  $\tau_i$  represents transport barriers in the quantity equation (18). Following Hallak (2005), we use distance to proxy for transport cost. Since trade is likely to decrease with distance from the destination market, we expect  $\delta < 0$ . We do not include the distance variable in the price equation to account for the "Alchian-Allen effect" that a per unit transport cost increases the relative demand for high quality goods (by lowering its relative price).<sup>7</sup> This is because the Alchian-Allen effect is primarily concerned with destination-varying prices, while we are concentrating on prices charged to a single destination.

We expect  $\alpha_1 - \alpha_4$  and  $\mu_1 - \mu_3$  to be positive based on the discussion in the previous section. Since manufactured products are not land-intensive, the expected signs on  $\alpha_6$  and  $\mu_3$  are unclear. We also expect  $\alpha_5$  to be negative because  $\sigma > 0$ . This is consistent with Hallak and Schott (2006), who assume a negative relationship between prices and the number of varieties a country produces.<sup>8</sup> Hummels and Klenow (2005) find strong evidence that a country's variety margin is proportional to its size, hence, including labor force in the structural estimation accounts

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<sup>7</sup> As the name suggests, this idea was originally proposed by Alchian and Allen (1964). See Hummels and Skiba (2004) for a broad overview of this literature.

<sup>8</sup> The basis for this assumption is that comparative advantage is associated with both relatively low prices (due to relatively low factor costs) and a relatively high number of varieties.

for unobserved product varieties. Finally, we expect the coefficient on trade barrier,  $\mu_5$ , to be negative.

The price and quantity equations (17) and (18) are jointly estimated by the method of seemingly unrelated regressions (SUR) by Zellner (1962). SUR, which is an extension of the linear regression model, allows correlated errors between equations that may seem unrelated at first look. The errors may be correlated across equations (17) and (18) for two reasons. First, both the equations are using the same data. Second, we use ‘average’ prices or *unit values* (which are computed by dividing total value by total quantity) instead of actual prices, since information on the latter is not usually available from trade data. Given that quantities are often inaccurately recorded by customs officials, the resulting unit values are also likely to be erroneous.<sup>9</sup> It would therefore be unrealistic to expect the equation errors to be uncorrelated.

## **5. Data and Related Issues**

### ***5.1. Data Sources***

The data on trade flows comes from Feenstra (2000). It contains information on unit values (f.o.b. value/quantity) of U.S. imports. This dataset is consistent with our theoretical model, in which we hold the demand for quality constant and allow quality to vary across suppliers. Our dataset primarily concentrates on trade flows for 1993-1996. Since manufactured materials have the most categories and are more likely to be influenced by capital abundance and exporter skill, we restrict the analysis to manufacturing trade flows (SITC 1 = 5-8) for differentiated goods. We also use data on non-manufacturing trade flows (SITC 1 = 1-4) so that we can extend our analysis to homogeneous goods such as wheat that are internationally traded in organized exchanges. We use Rauch’s (1999) classification of differentiated sectors. He uses both

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<sup>9</sup> U.S. General Accounting Office (1995) discusses measurement and classification problems in U.S. import data.

a “liberal” and a “conservative” standard in his classification. We use the liberal standard because it is more stringent in the classification of differentiated products.

Our sample is restricted to 58 countries in order to prevent zero-trade observations from dominating the sample. Since the incidence of zero trade is larger for smaller countries, we only concentrate on relatively large countries. Hence, we include countries with a population larger than 3 million, and with more than \$1 million U.S. imports of differentiated goods in these industries. Since Hallak (2005) reports that Hungary has poor quality data at the sector level, we drop it from the sample. In addition, we omit Algeria, Iran and Libya due to the lack of data on their export unit values.

Information on physical stock of capital, land endowments, labor force, and FDI inflows (as percentage of GDP) is available from the World Development Indicator (WDI). We use this information to construct the stock of physical capital and land available to each worker. The stock of human capital or skill available to each worker is usually proxied by some measure of educational attainment.<sup>10</sup> Following Schott (2004), we use the percentage of population with at least secondary education (in comparison to the percentage of population with at most primary education) as a proxy for skill. Alternatively, we use average years of schooling to measure skill. Data on educational attainment comes from Barro and Lee (2000). Finally, we use spending on Research and Development (R&D) activities (as percentage of GDP) and number of researchers involved in R&D activities as proxies for technology. Data on R&D expenditure and researchers comes from the United Nations Human Development Report Statistics (2005). Table 1 lists the variables used in the regressions and their data sources.

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<sup>10</sup> Although the terms “human capital” and “skill” may have different meanings, we use them interchangeably throughout this paper.

### ***5.2. Detecting and Removing Erroneous Observations***

The database on U.S. imports has considerable measurement error. Information on imports is recorded according to hundreds of thousands of customs declaration forms and is thus susceptible to both inaccurate recording and misclassification. To detect and remove erroneous observations, we proceed as follows. First, we compute the geometric mean of unit values across countries, excluding the observations with maximum and minimum values. To deal with outliers, we remove observations with extreme unit values (four times above or below the category mean) and observations with very low quantity (below the lower of 50 units or a quarter of the category mean quantity). Some countries may be active in only a few SITC 10-digit categories, which make the results very sensitive to measurement errors. We therefore adopt the following convention. A country is “active” in a 10 digit category if it has a non-missing observation. A country is “active” in a 2-digit sector if it has at least two active categories. Otherwise, the unit value at the sectoral level takes a missing value. Finally, we drop re-exported goods from our data. These are goods for which the country of origin may differ from the country of shipment. Value may be added at the country of shipment, which may bias the prices upward and consequently give us incorrect signals about the quality of the products.

### ***5.3. Construction of the Fisher Ideal Index***

Instead of using each country’s mean export price or total export quantity to represent the price and quantity variables in equations (17) and (18), we use a Fisher Ideal Index (e.g., U.S. Bureau of Economic Analysis) to construct price and quantity indices for each exporter.<sup>11</sup> Such an aggregate index tends to suffer from the incidence of composition problems. For instance, if a category includes different goods, differences in prices may not only reflect differences in quality,

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<sup>11</sup> The STATA code used to construct the price and quantity indices are available online: <http://mypage.iu.edu/~hfaruq/research.htm>

but differences in the composition of products within that category as well. To keep such problems to a minimum, we compute the unit values or average price at the 10 digit level in the Harmonized System, which is the finest possible level of aggregation. We then use these unit values to construct the Fisher Index.

The Fisher price index is a geometric-weighted average of two price indices. In this case, the first index will use the country's own export quantities to weight market-categories and the second index will use world export quantities to weight market-categories. Thus, the Fisher price index captures the extent to which an exporter's prices are high or low relative to other prices in the same market category. This ensures, for example, that a country will not be assigned a higher price index if it only produces high price products in a limited number of categories.

Let  $v_{jis}$ ,  $x_{jis}$ , and  $p_{jis}$  ( $= v_{jis}/x_{jis}$ ) denote the total value, quantity, and price of exports from country  $j$  to country  $i$  in category  $s$ , and  $v_{Wis}$ ,  $x_{Wis}$ , and  $p_{Wis}$  ( $= v_{Wis}/x_{Wis}$ ) denote the total value, quantity and price of world exports to country  $i$  in category  $s$ . Then, the Fisher price index is given by:

$$\left[ \frac{\sum_{i \neq j} \sum_{s \in X_{jis}} p_{jis} x_{jis}}{\sum_{i \neq j} \sum_{s \in X_{jis}} p_{Wis} x_{jis}} \right]^{1/2} \left[ \frac{\sum_{i \neq j} \sum_{s \in X_{jis}} p_{jis} x_{Wis}}{\sum_{i \neq j} \sum_{s \in X_{jis}} p_{Wis} x_{Wis}} \right]^{1/2} \quad (19)$$

The Fisher quantity index can be similarly constructed by using the country's own and world prices to weight export quantities. This is more useful than simply summing up the total quantity of goods exported by each country, since different goods are expressed in different units (e.g., the number of shirts versus kilogram of steel) and have different valuations (e.g., a Volvo is more expensive than 1000 Staedler ballpoint pens). The Fisher quantity is given by:

$$\left[ \frac{\sum_{i \neq j} \sum_{s \in X_{jis}} p_{jis} x_{jis}}{\sum_{i \neq j} \sum_{s \in X_{jis}} p_{jis} x_{Wis}} \right]^{1/2} \left[ \frac{\sum_{i \neq j} \sum_{s \in X_{jis}} p_{Wis} x_{jis}}{\sum_{i \neq j} \sum_{s \in X_{jis}} p_{Wis} x_{Wis}} \right]^{1/2} \quad (20)$$

Once we construct the price and quantity indices given by (19) and (20), we use them in the estimation of equations (17) and (18).

## **6. Results**

### ***6.1. Patterns of Specialization***

We observe two specific patterns in the data. First, rich countries are more likely to export more expensive varieties in larger quantities. Second, there is significant variation in relative endowments, foreign investments, and technology to explain variation in export price. The first observation is based on Figure 1, in which we divide the countries into five specific income cohorts using the World Bank's Income Group Classification (2006): (i) high income OECD countries, (ii) high income non-OECD countries, (iii) upper middle income countries, (iv) lower middle income countries, and (v) low income countries. We observe that the mean price and quantity indices are generally increasing in exporter income. If we assume that price movements adequately reflect changes in quality composition of exports, this would imply that rich countries, on average, produce more expensive products in larger quantities, which is also consistent with these countries producing better quality products. Table 3 provides some support to this conjecture. It lists the countries with the highest and lowest average export price indices during 1993-1996 and shows that countries like Norway and Sweden export more expensive varieties than countries like Syria and Bangladesh.

Next, we plot the Fisher price index against capital per worker and R&D spending in Figures 2 and 3. While we do not find a clear pattern for homogeneous products, we observe that price of differentiated products are positively correlated with both endowments and technology. In fact, the price-endowment and the price-technology relationships exhibit a great deal of variation. To analyze this variation further, we take the mean price index, as well as capital per worker, FDI,

and R&D spending in Table 2 and compare them with their respective standard deviations. The resulting coefficient of variation for export price is 0.24, while those for capital per worker, FDI, and R&D spending are 0.91, 1.03, and 1.04 respectively. This gives us significant variation with which to try and explain price variation.

## 6.2. Estimation Results

We now turn our attention to the estimation results. Table 4 reports price and quantity estimates from both the standard price regression and the system of equations given by (17) and (18). Columns (2) and (3) show the unweighted SUR results, while columns (4) and (5) present estimation results with observations weighted according to the precision of the price index. Let  $G_i$  represent the number of “active” categories of country  $i$ . We assume that the precision of the price index is positively related to  $G_i$  and use weights  $w = \sqrt{\ln(G_i)}$ . All estimations are performed with heteroskedasticity-robust standard errors. Year dummies are included but not reported.

The unweighted and weighted regressions show similar results: countries with larger capital stock per worker, higher R&D activity, and greater FDI inflows tend to produce higher quality products. In addition, larger countries tend to export at lower quality-adjusted prices (i.e.  $\alpha_5$ , the coefficient on labor, is negative as expected). These results are in marked contrast with the estimates obtained from the traditional price regression. As column (1) shows, physical capital is found to affect quality, while the effect of R&D on quality is not detectable.

Notice that all of the regressions fail to identify the effects of skill per worker on quality. This may be due to multicollinearity, but the variance inflation factor and the tolerance indicators both suggest otherwise. Another possibility is that our measure of educational attainment (percentage of population with at least secondary levels of education) is not a good indicator of

human capital. Therefore, we use average years of schooling as another proxy for human capital. In addition, we use the number of researchers involved in R&D activities as an alternate measure of domestic technology.

Our estimation results using these other measures of human capital and technology are summarized in Table 5. The results broadly confirm our previous findings: (i) R&D, FDI, and capital per worker are important determinants of high quality exports, (ii) prices are inversely related to country size, and (iii) the effects of human capital on quality is unclear. Wozzmann (2003) suggests that mean schooling misspecifies the relationship between education and the stock of human capital. The estimates for the quantity equation also support this notion. In both Tables 4 and 5, we observe that the impact of schooling on export quantity is barely recognizable, while the effects of capital and labor seem much stronger. Therefore, it is more likely that our problems may have to do with weaknesses associated with our proxies for human capital, rather than with the theory itself.

In almost all of the regressions in Tables 4 and 5, we find that land has a very weak or negligible impact on the quality of exports. This is because manufactured products are not land-intensive. However, with agricultural products, we can expect to see a more substantial role for land supply. We find some support for this conjecture in Table 6, which presents the regression results for homogeneous products. Since these products do not feature a prominent quality margin, we observe that many of our previous results have been reversed. More specifically, we find that the coefficients on labor force and technology are no longer significant, while those on FDI inflow and land are now highly negative. This is because (a) such products are land intensive (rather than technology intensive) (b) they do not represent sectors in which foreign investment generally takes place, and (c) they do not feature a variety margin.



### 6.3. Sensitivity Tests

To examine the validity of our results, we take the SUR in Table 4 as our base model and make gradual changes to study the effect of the change on the coefficient of interest. Table 7 summarizes the results. We do not report the estimates from the quantity equation, since we are primarily interested in the quality estimates which can be inferred from the price equation.

In column (1), we focus exclusively on consumer goods. Since we do not explicitly model intermediate goods, we want to ensure that their presence in the dataset does not bias the results. Therefore, we construct price and quantity indices based on consumer goods *only*, carry out SUR, and compare the estimates with those reported in Table 4. In general, we find no major differences in terms of sign or significance. All of our previous findings hold: the coefficients on capital per worker, R&D spending, FDI inflow, land and labor force are all significant and have the expected signs while the effects of schooling and distance on quality are not detectable. The close similarity between the estimates suggests that intermediate goods have not adversely affected the results.

The next specification examines the possibility that export prices may be arbitrarily high or low due to exchange rate fluctuations. We therefore deflate export prices using the GDP deflator and report our findings from the resulting regression in column (2). We find that the results are more or less identical to those shown in column (1). If anything, the effect of country size on prices is even stronger than before.

In columns (3) and (4), we remove observations with the top ten and bottom ten percentiles of export categories. The idea is to examine whether extreme prices are largely attributable to unobserved product varieties rather than quality. The signs and significance of the variables of interest largely remain unchanged. Specifications in columns (5) and (6) examine the result when countries in the top and bottom ten percentiles of income are excluded from the sample. This suggests that the results are not significantly driven by very high or very low income

countries. Finally, in specification (7), we remove from the sample the four countries which had missing information for at least two years over the period 1993-1996. The objective is to address concerns that countries with poorer data collection capacities may have nonzero correlations with some independent variables of interest. Fortunately, curtailing our sample in this way does not affect any of the main results of the paper.

## **7. Conclusion**

Although several empirical studies have examined the relationship between a country's physical capital stock and the quality of its exports, no study has previously analyzed the links between technology and quality empirically. This paper shows that both R&D activities and FDI inflows are important determinants of quality. These results cannot be replicated by using a reduced form specification in which price is regressed against various explanatory variables. Although this kind of specification has been used in several studies, it has a number of limitations. First, it assumes that price differences arise entirely from quality differences. Second, it ignores the correlation between error terms in the price and quantity equations. We address both of these concerns in this paper. We use price as an indicator, rather than an exact measure, of quality and also use a two-equation system in price and quantity to allow cross-equation error correlation. This method of estimation allows us to reach the conclusion that the quality of exports does not depend on technology or factor endowments exclusively, but on some combination of the two variables. Our main result is thus intuitive and also provides a middle ground to the 'factor endowment versus technology' debate.

Surprisingly, our regressions fail to find the coefficient on human capital to be statistically significant in any of our specifications. This may be due to multicollinearity, but the variance inflation factor indicates otherwise. We experiment with different measures of schooling but fail

to find the desired results. As we discussed before, this may be due to weaknesses associated with our proxies for human capital, rather than with the theory itself.

This paper, like other studies on trade and quality, does not address whether managerial ability, mark-up differences, or a country's bargaining position significantly affect its export price. If so, export prices may be biased indicators of quality. However, these variables are not only difficult to incorporate in the theoretical model, but also difficult to measure empirically. Another shortcoming of this study is that it suffers from the usual limitations of cross-country studies, such as measurement and comparability problems. Finally, it may be also beneficial to study this question at the firm level. This will help us better comprehend the mechanisms underlying the quality upgrading process, such as how firms make investment decisions when they choose to upgrade quality and how they allocate their resources as a result.

Despite these limitations, it is still beneficial to produce some evidence on quality variation. They show that the dispersion in quality is not the upshot of a random process, but varies systematically across countries with specific attributes. Our findings also open the door for future research in several related areas. For example, what are the institutional variables that facilitate the production and export of high-quality goods? Or, how persistent are the effects of technology and FDI on quality? In an era of globalization, these questions have important implications for firms and wages. In particular, policymakers in developing countries will find these questions interesting, since quality upgrading is an important stage of their development process.

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**Table 1: Variables and Data Sources**

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<i>Years:</i>	1993 – 1996
<i>Countries:</i>	Argentina, Australia, Austria, Bangladesh, Belgium-Luxembourg (treated as one country), Brazil, Bulgaria, Canada, Chile, China, Colombia, Costa Rica, Denmark, Dominican Republic, Ecuador, Egypt, Finland, France, Germany, Greece, Guatemala, Hong Kong, India, Indonesia, Ireland, Israel, Italy, Japan, Lebanon, Malaysia, Mexico, Morocco, Netherlands, New Zealand, Nigeria, Norway, Pakistan, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Saudi Arabia, Singapore, South Korea, Spain, Sri Lanka, Sweden, Switzerland, Syria, Thailand, Tunisia, Turkey, United Kingdom, Uruguay, Venezuela, Vietnam (58 countries)
<i>Price and Quantity:</i>	Feenstra (2000)
<i>Capital and Land per worker:</i>	World Development Indicator Online
<i>Foreign Direct Investment:</i>	World Development Indicator Online
<i>Schooling:</i>	Barro and Lee (2000) 1) Ratio between population with at least secondary education and population with at most primary education 2) Average years of schooling
<i>Technology:</i>	Human Development Report (2005) 1) R & D Spending (% of GDP) 2) Researchers in R & D
<i>Distance:</i>	Jon Haveman's International Trade Data <a href="http://www.eiit.org/Trade.html">http://www.eiit.org/Trade.html</a>

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**Table 2: Summary Statistics**

	Observations	Mean	Standard Deviation	Minimum	Maximum
Fisher Price (Differentiated Goods)	231	1.24	0.30	0.71	2.02
Fisher Price (Homogeneous Goods)	231	1.07	0.16	0.70	2.05
Fisher Quantity (Differentiated Goods)	231	0.03	0.05	0.003	0.29
Fisher Quantity (Homogeneous Goods)	231	0.04	0.05	0.001	0.25
FDI Net Inflows (% of GDP)	224	2.05	2.12	0.001	13.84
Secondary schooling (divided by primary educational attainment)	216	1.13	1.17	0.10	6.90
Average Years of Schooling	212	7.12	2.48	2.32	11.82
Land per worker (square km)	232	0.08	0.14	0.003	0.85
Spending on R & D (% of GDP)	204	1.24	1.14	0.07	5.10
Researchers in R & D (per million people)	180	1,912.55	1,748.51	29	7431
Distance (square km)	232	5,783.53	2,417.18	1,076.36	14,478.01
Capital per worker (constant 2000 \$)	218	4,421.19	4,439.19	106.23	19,584.56
Labor Force	232	33,526,402	100,373,552	1,038,655	709,000,000



**Table 3: Highest and Lowest Average Export Prices (1993-1996)**

Top 5 Exporters		Bottom 5 Exporters	
<u>Country</u>	<u>Average Export Price</u>	<u>Country</u>	<u>Average Export Price</u>
Norway	1.85	Syria	0.77
Finland	1.83	Bangladesh	0.79
France	1.75	Paraguay	0.86
Denmark	1.65	Egypt	0.87
Sweden	1.63	Romania	0.88

**Table 4: Price and Quantity Estimates for Differentiated Products**

	Traditional OLS	Unweighted SUR		Weighted SUR	
	(1) Price	(2) Price	(3) Quantity	(4) Price	(5) Quantity
<i>Capital per worker</i>	0.084 (2.65)***	0.087 (3.35)***	0.294 (1.97)**	0.086 (3.40)***	0.299 (1.97)**
<i>Secondary Schooling</i>	0.002 (0.14)	− 0.005 (0.35)	0.128 (1.48)	− 0.006 (0.42)	0.141 (1.63)
<i>Land per worker</i>	0.015 (1.45)	0.012 (1.31)	− 0.262 (5.32)***	0.012 (1.32)	− 0.290 (5.31)***
<i>Labor Force</i>		− 0.021 (2.24)**	0.735 (13.37)***	− 0.022 (2.43)**	0.742 (13.59)***
<i>R &amp; D Spending</i>	0.030 (1.48)	0.043 (2.47)**		0.038 (2.26)**	
<i>FDI Inflows</i>	0.026 (3.01)***	0.023 (2.58)**		0.021 (2.51)**	
<i>Distance</i>			− 0.419 (2.69)***		− 0.436 (2.87)***
<i>OECD Dummy</i>	0.176 (3.29)***	0.152 (3.00)***	− 0.335 (1.21)	0.162 (3.29)***	− 0.349 (1.26)
<i>Non-OECD High Income Dummy</i>	− 0.021 (0.20)	− 0.086 (0.86)	0.503 (0.91)	− 0.070 (0.73)	0.496 (0.91)
<i>Low Income Dummy</i>	0.058 (0.62)	0.099 (1.17)	− 0.548 (1.11)	0.103 (1.25)	− 0.592 (1.20)
<i>Lower Middle Income Dummy</i>	0.021 (0.37)	0.045 (1.03)	− 0.393 (1.60)	0.052 (1.21)	− 0.376 (1.51)
<i>Constant</i>	− 0.452 (1.71)*	− 0.141 (0.56)	− 15.96 (8.12)***	− 0.122 (0.50)	− 15.94 (8.26)***
<i>Observations</i>	194	194		194	

Notes: Absolute values of  $z$  statistics in parentheses (except column 1, which reports  $t$ -statistics from OLS regression). All variables are in logs. Time dummies are included, but not reported. Standard errors are heteroskedasticity robust. \*\*\*, \*\*, \* represents significance at the 1%, 5%, and 10% level, respectively.

Weighted regressions use weights  $w = \sqrt{\ln(G_i)}$ , where  $G_i$  is the number of “active” categories of country  $i$ .

**Table 5: Price and Quantity Estimates Using Alternate Measures of Human Capital and Technology**

	Using Average Years of Schooling		Using No. of Researchers in R&D	
	(1) Price	(2) Quantity	(3) Price	(4) Quantity
<i>Capital per worker</i>	0.078 (3.02)***	0.327 (2.10)**	0.101 (3.74)***	0.426 (2.62)***
<i>Schooling</i>	− 0.069 (1.66)*	0.050 (0.20)	− 0.013 (0.86)	0.080 (0.89)
<i>Land per worker</i>	0.016 (1.66)*	− 0.289 (5.06)**	0.014 (1.49)	− 0.263 (4.36)***
<i>Labor Force</i>	− 0.021 (2.25)**	0.725 (13.19)***	− 0.027 (2.71)***	0.699 (11.66)***
<i>Domestic Technology</i>	0.048 (2.88)***		0.075 (4.77)***	
<i>FDI Inflows</i>	0.023 (2.60)***		0.017 (1.80)*	
<i>Distance</i>		− 0.405 (2.58)**		− 0.515 (2.66)***
<i>OECD Dummy</i>	0.172 (3.30)***	− 0.292 (0.99)	0.052 (0.94)	− 0.389 (1.34)
<i>Non-OECD High Income Dummy</i>	− 0.056 (0.55)	0.523 (0.91)	− 0.165 (1.66)*	0.509 (0.90)
<i>Low Income Dummy</i>	0.023 (0.25)	− 0.325 (0.59)	0.282 (2.98)***	− 0.185 (0.35)
<i>Lower Middle Income Dummy</i>	0.027 (0.64)	− 0.310 (1.23)	0.083 (1.88)*	− 0.166 (0.64)
<i>Constant</i>	− 0.069 (0.25)	− 16.33 (7.94)***	− 0.639 (2.28)**	− 15.60 (7.09)***
<i>Observations</i>	194		170	

Notes: Absolute values of  $z$  statistics in parentheses (except column 1, which reports  $t$ -statistics from OLS regression). All variables are in logs. Time dummies are included, but not reported. Standard errors are heteroskedasticity robust. \*\*\*, \*\*, \* represents significance at the 1%, 5%, and 10% level, respectively.

**Table 6: Price and Quantity Estimates for Homogeneous Products**

	Using Average Years of Schooling		Using No. of Researchers in R&D	
	(1) Price	(2) Quantity	(3) Price	(4) Quantity
<i>Capital per worker</i>	0.074 (4.11)***	0.373 (2.03)**	0.066 (3.40)***	– 0.267 (1.44)
<i>Schooling</i>	– 0.007 (0.23)	0.540 (1.81)*	– 0.002 (0.27)	0.279 (2.70)***
<i>Land per worker</i>	– 0.017 (2.45)**	0.189 (2.80)***	– 0.019 (2.74)***	0.225 (3.24)***
<i>Labor Force</i>	0.003 (0.46)	0.256 (3.96)***	– 0.001 (0.09)	0.202 (2.94)***
<i>Domestic Technology</i>	0.005 (0.39)		0.004 (0.33)	
<i>FDI Inflows</i>	– 0.040 (6.30)***		– 0.044 (6.41)***	
<i>Distance</i>		– 0.750 (3.96)***		– 0.909 (3.94)***
<i>OECD Dummy</i>	– 0.043 (1.20)	0.160 (0.46)	– 0.037 (0.92)	0.370 (1.11)
<i>Non-OECD High Income Dummy</i>	– 0.100 (1.42)	0.467 (0.69)	– 0.093 (1.30)	0.719 (1.10)
<i>Low Income Dummy</i>	0.047 (0.75)	– 0.325 (0.50)	0.077 (1.12)	0.155 (0.25)
<i>Lower Middle Income Dummy</i>	0.064 (2.15)**	– 0.639 (2.15)**	0.067 (2.11)**	– 0.663 (2.23)**
<i>Constant</i>	– 0.586 (3.01)***	1.03 (0.42)	– 0.404 (1.44)	3.42 (1.33)
<i>Observations</i>	194		170	

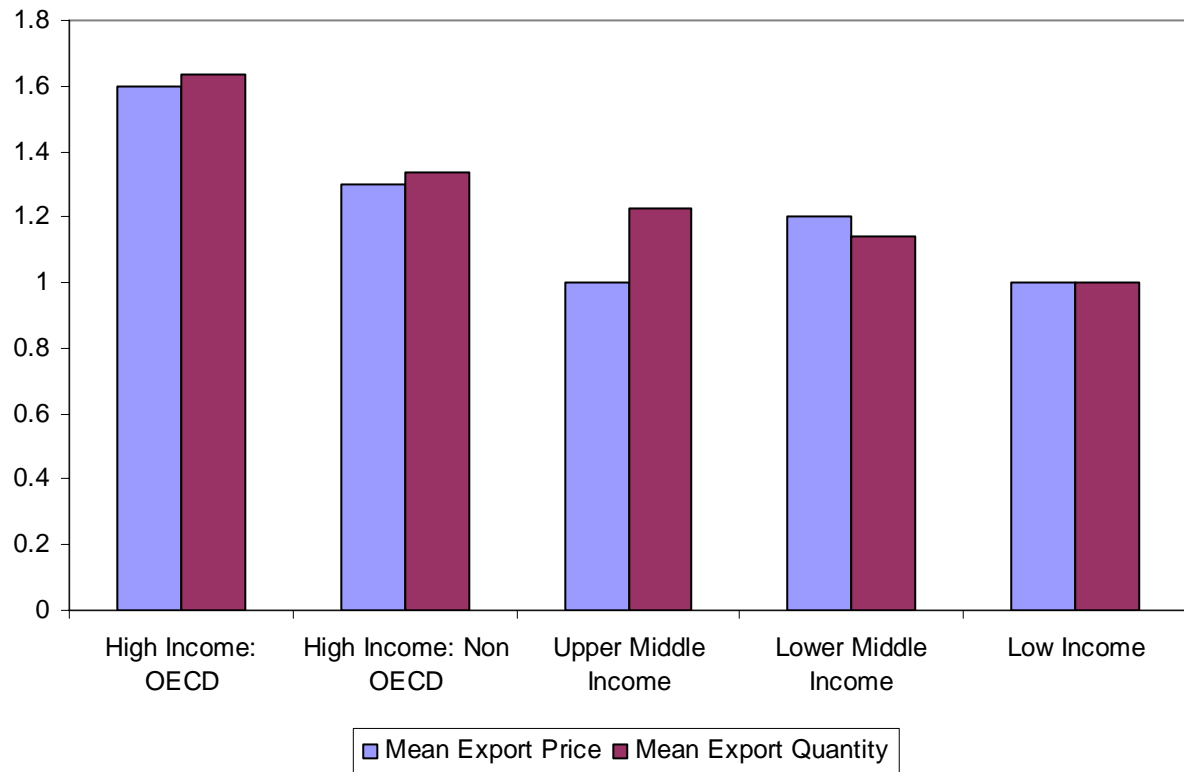
Notes: In columns (1) and (2), R&D spending is used as proxy for technology. In columns (3) and (4), educational attainment (% of population with at least secondary education in comparison with those with at most primary education) is used as a proxy for human capital. Absolute values of  $z$  statistics are in parentheses. All variables are in logs. Time dummies are included, but not reported. Standard errors are heteroskedasticity robust. \*\*\*, \*\*, \* represents significance at the 1%, 5%, and 10% level, respectively.

**Table 7: Sensitivity Analysis (Price Estimates for Differentiated Products Only)**

	(1) Consumer Imports	(2) GDP-Deflator Adjusted Price	(3) Top 10% Categories Excluded	(4) Bottom 10% Categories Excluded	(5) Top 10% Income Excluded	(6) Bottom 10% Income Excluded	(7) Countries with Frequently Missing Obs. Excluded
<i>Capital per worker</i>	0.072 (2.89)***	0.637 (2.61)***	0.064 (2.27)**	0.074 (3.31)***	0.087 (2.89)***	0.089 (3.17)***	0.089 (3.41)***
<i>Secondary Schooling</i>	– 0.009 (0.68)	0.162 (1.26)	– 0.011 (0.73)	– 0.007 (0.56)	– 0.019 (1.14)	– 0.003 (0.20)	– 0.008 (0.52)
<i>Land per worker</i>	0.021 (2.29)**	0.208 (0.50)	0.034 (3.15)***	0.017 (2.16)**	0.010 (0.98)	0.010 (0.96)	0.013 (1.39)
<i>Labor Force</i>	– 0.015 (1.71)*	– 0.278 (2.77)***	– 0.022 (2.11)**	– 0.019 (2.23)**	– 0.018 (1.76)*	– 0.027 (2.49)**	– 0.022 (2.24)**
<i>R &amp; D Spending</i>	0.047 (2.77)***	0.578 (3.52)***	0.056 (3.07)***	0.032 (2.08)**	0.045 (2.38)**	0.046 (2.28)**	0.036 (2.06)**
<i>FDI Inflows</i>	0.031 (3.54)***	0.412 (3.86)***	0.032 (2.44)**	0.017 (2.26)**	0.024 (1.87)*	0.021 (2.07)**	0.023 (2.50)**
<i>Constant</i>	– 0.087 (0.36)	– 0.667 (0.30)	– 0.129 (0.42)	– 0.090 (0.42)	– 0.198 (0.71)	– 0.057 (0.21)	– 0.044 (0.20)
<i>Observations</i>	194	160	171	176	170	178	186

**Notes:** SUR estimates from the quantity equation are not reported. Absolute values of  $z$  statistics are in parentheses. All variables are in logs. Income cohort and time dummies are included, but not reported. Standard errors are heteroskedasticity robust. \*\*\*, \*\*, \* represents significance at the 1%, 5%, and 10% level, respectively.

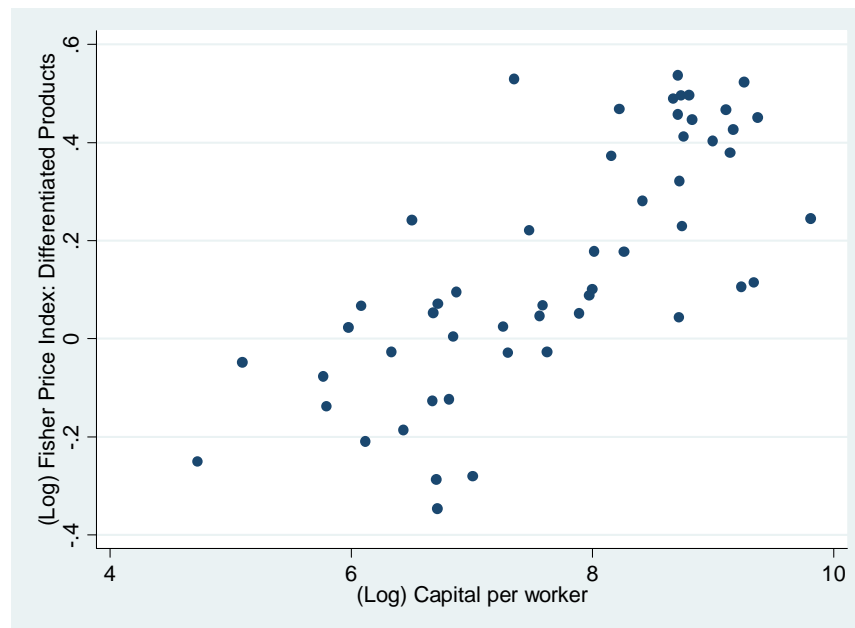
**Figure 1: Fisher Export Price and Quantity Index by Income Group (1993-1996)**



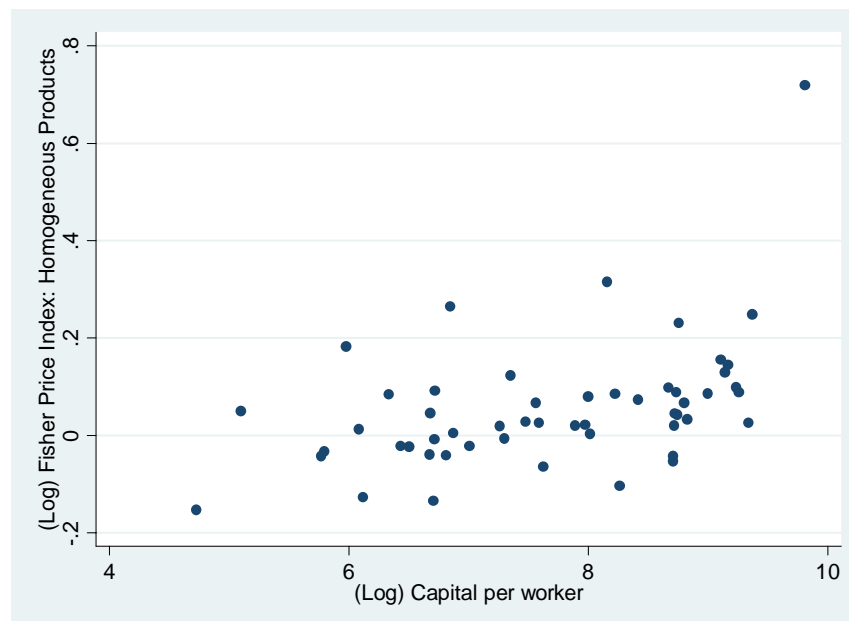
Notes: Mean price and quantity index for differentiated goods used;  
All indices normalized with respect to low-income countries.

**Figure 2: Relationship between Fisher Price Index and Capital per Worker (1993)**

**(a) Differentiated Products**

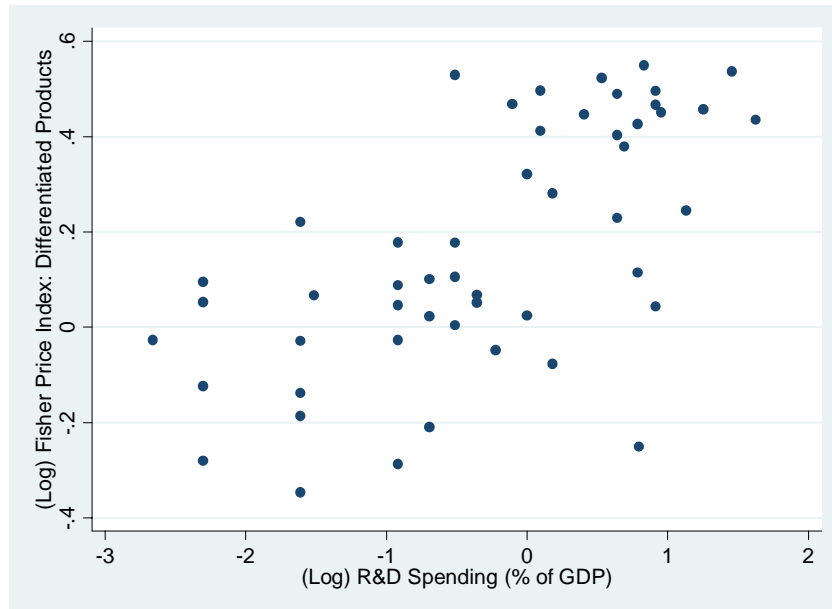


**(b) Homogeneous Products**



**Figure 3: Relationship between Fisher Price Index and R&D Spending (1993)**

**(a) Differentiated Products**



**(b) Homogeneous Products**

